A Pilot Study of T50, RVP and Ambient Temperature Effects on PM Emissions from Light-Duty GDI Vehicles

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Background and Objectives (1/2)

RVP: Reid vapor pressure
T50: 50% distillation point
T90: 90% distillation point
PMI: particulate matter index

- EPA/DOE/CRC EPAct Study: The most recent study of the exhaust emissions impacts of T50 and RVP
  - Fuel impacts investigated: Ethanol, aromatics, RVP, T50, T90 (+PMI later)
  - ~950 tests (27 fuels, 15 PFI vehicles, LA92 test cycle, 75ºF)
  - The emissions test program was conducted at Southwest Research Institute in 2009/2010
  - Final report and associated files are available at the following site: https://www.epa.gov/moves/epactv2e-89-tier-2-gasoline-fuel-effects-study
    - "Final Report on EPA's Analysis of EPAct/V2/E-89 Dataset", 2013
  - EPAct PM dataset was later reanalyzed using the PMI. The results were reported in Butler, A. et al., "Influence of Fuel PM Index and Ethanol Content on Particulate Emissions from Light-Duty Gasoline Vehicles", SAE paper 2015-01-1072

Background and Objectives (2/2)

EPAct study showed T50 had modest influence on PM for PFIs, while RVP had none

EPAct PM models

	Model Coefficients (β)							
	Intercept	EtOH	Arom	RVP	T50	T90	EtOH*EtOH	T50*T50
Model name	3	4	5	6	7	8	9	10
PM_bag1	0.65590	0.15820	0.38330		0.05500	0.29230		0.09350
PM_bag2	-1.31070	0.11260	0.16620			0.10720		

- Could these parameters of modest/no influence in PFIs be important in GDIs?
  - Also at low test temperatures
- To what extent should they be included (or controlled) in future studies?

Test Vehicles

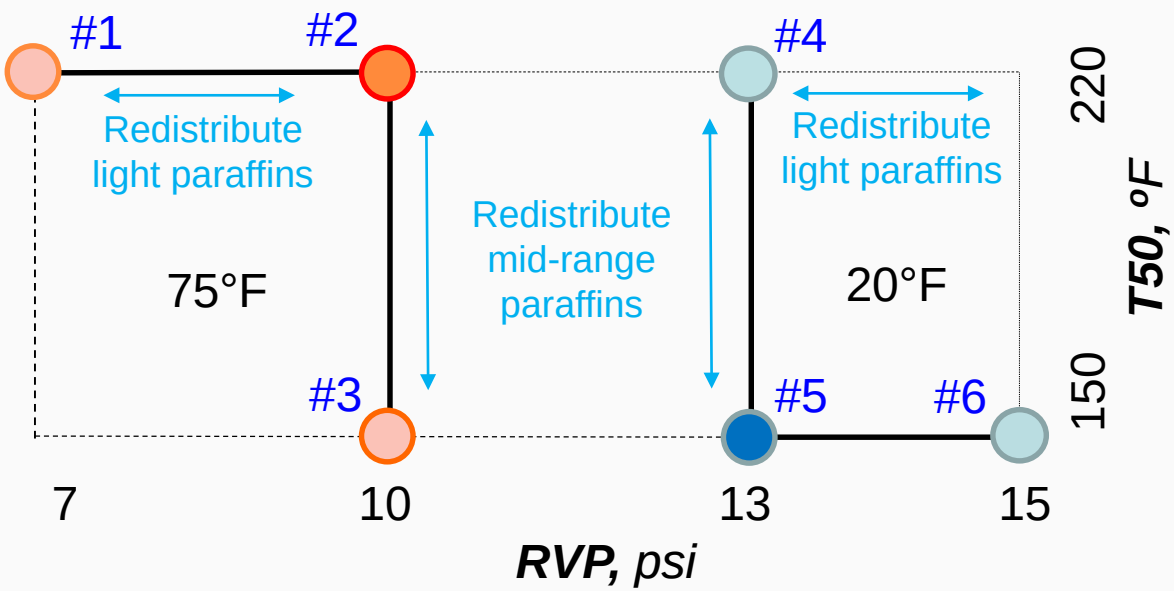
Test vehicles represented a range of mainstream GDI engine technologies

Model Year	Make/Model	Engine
2016	Acura ILX	2.4L I4 GDI
2015	Ford F150 Eco-Boost	2.7L V6 GDI
2014	Mazda 3	2.0L I4 GDI
2013	Chevrolet Malibu	2.4L I4 GDI
2015	Honda Civic*	1.5L I4 GDI
2016	Ford Fiesta Eco-Boost*	1.0L I3 GDI

*Tested by ECCC

Test Fuel Matrix

- RVP and T50 values spanned range of summer and winter market fuels
- Other properties based on Tier 3 cert fuel, e.g., aromatics distribution
- A common preblend containing all aromatics, olefins and all of ethanol constituted 40%v of each fuel. The remaining 60%v consisted of saturates

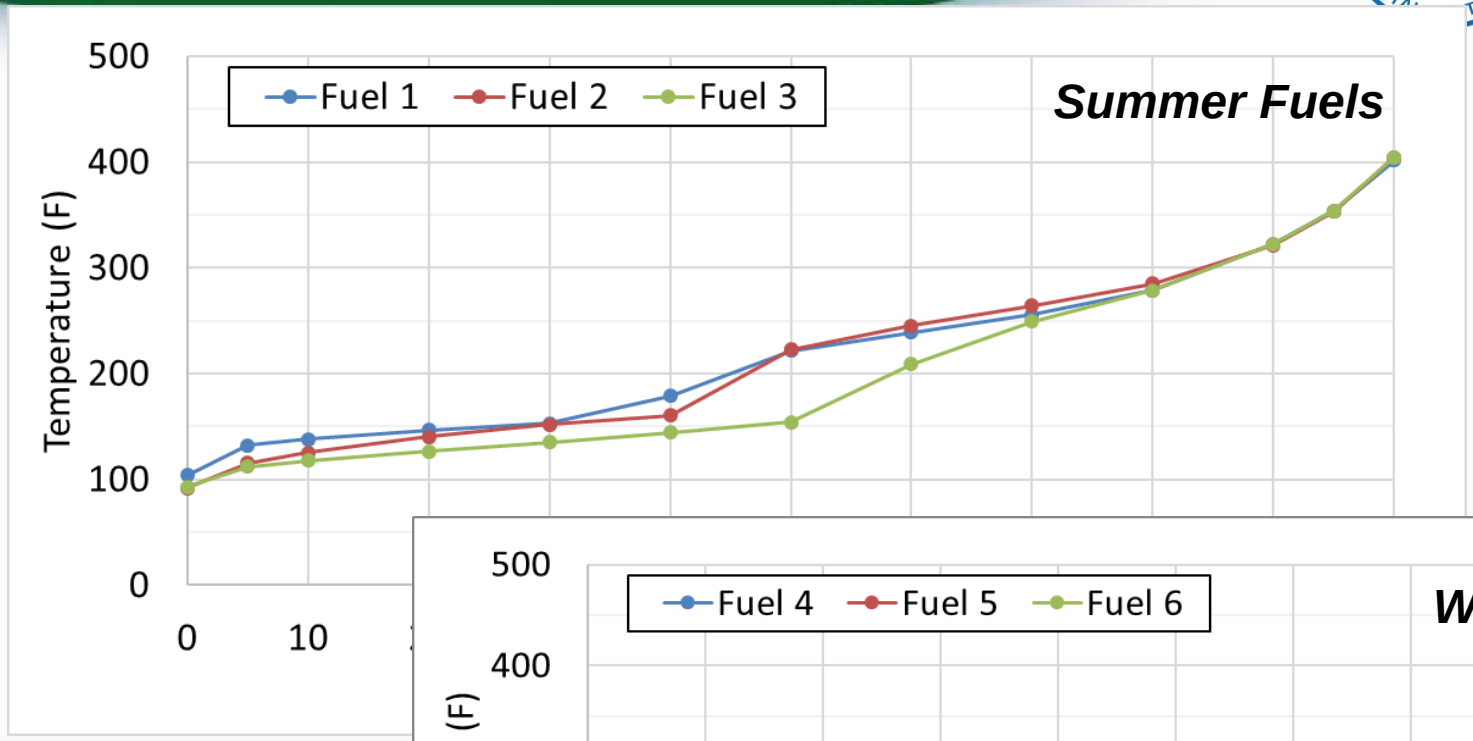


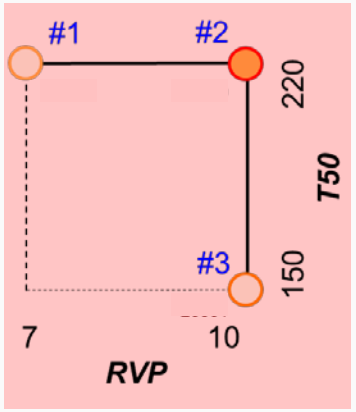
Test Fuel Properties

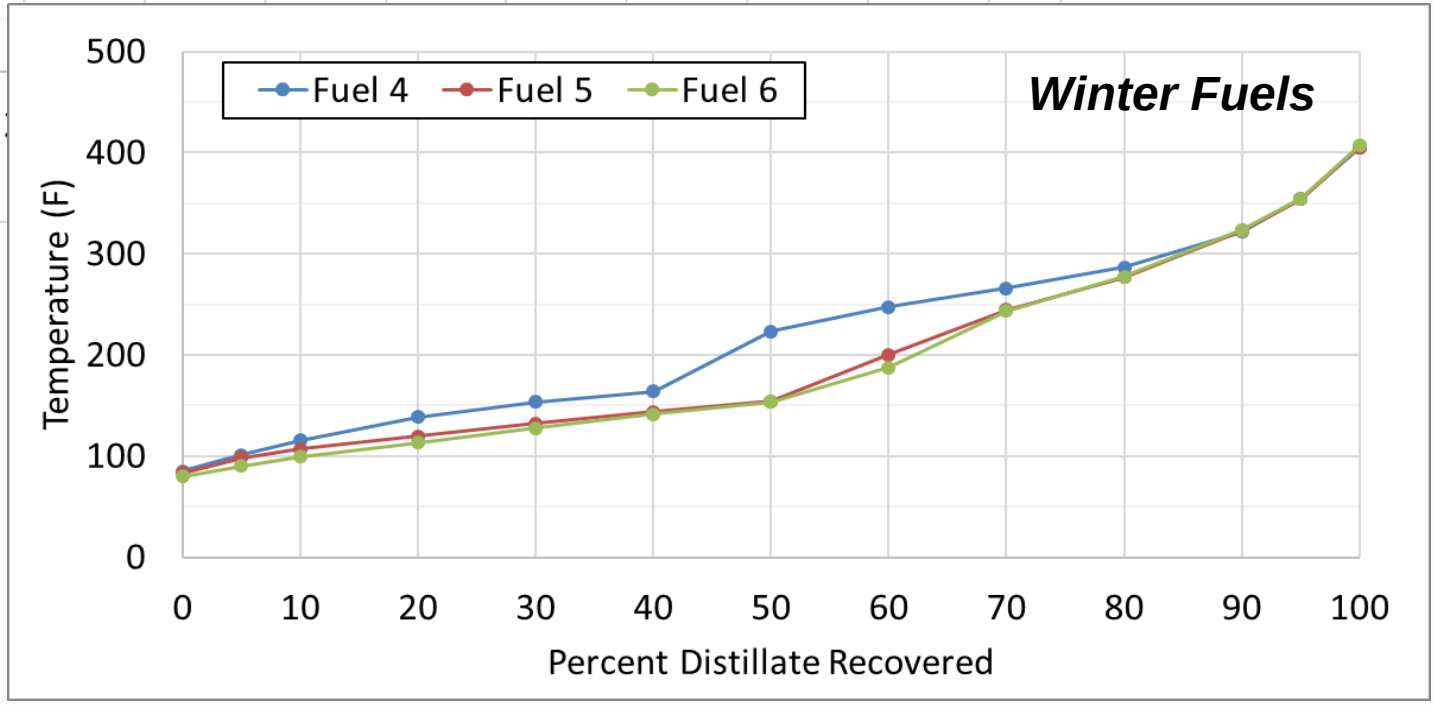
Parameter	ASTM method	Unit	Summer Fuels			Winter Fuels		
			#1	#2	#3	#4	#5	#6
T50	**D86**	**°F**	**222**	**223**	**154**	**223**	**154**	**153**
T90			322	321	323	322	323	323
RVP	**D5191**	**psi**	**6.9**	**9.7**	**9.8**	**13.0**	**13.2**	**15.0**
Total Aro	D5769	%m	24.5	24.3	24.5	24.3	24.3	24.6
C6 Aro			0.5	0.5	0.5	0.5	0.5	0.5
C7 Aro			5.9	5.9	6.0	5.9	6.0	6.1
C8 Aro			6.3	6.2	6.3	6.2	6.3	6.4
C9 Aro			6.1	6.1	6.1	6.1	6.0	6.1
C10+ Aro			5.7	5.6	5.5	5.7	5.5	5.6
PM Index	Per Honda	-	2.03	2.03	2.00	2.09	2.06	2.08
EtOH	D5599	%v	9.8	9.9	9.8	9.9	10.1	9.9
Olefins	D6550	%v	4.3	3.8	4.0	3.9	3.7	3.9
Sulfur	D5453	ppm	7.0	7.1	6.9	7.0	7.7	8.5
(R+M)/2	D2699/D2700	-	88.1	88.2	87.9	88.0	88.0	88.3
RON	D2699	-	91.7	91.7	91.5	91.5	91.4	92.0

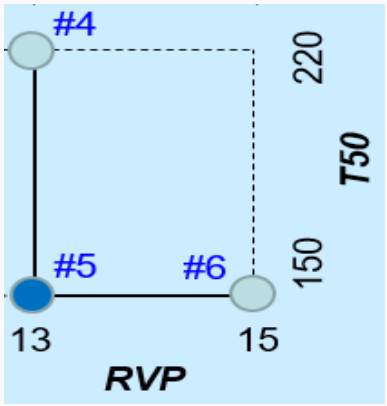
Property values shown are averages of results from 3+ labs.

Test Fuel Distillation Profiles







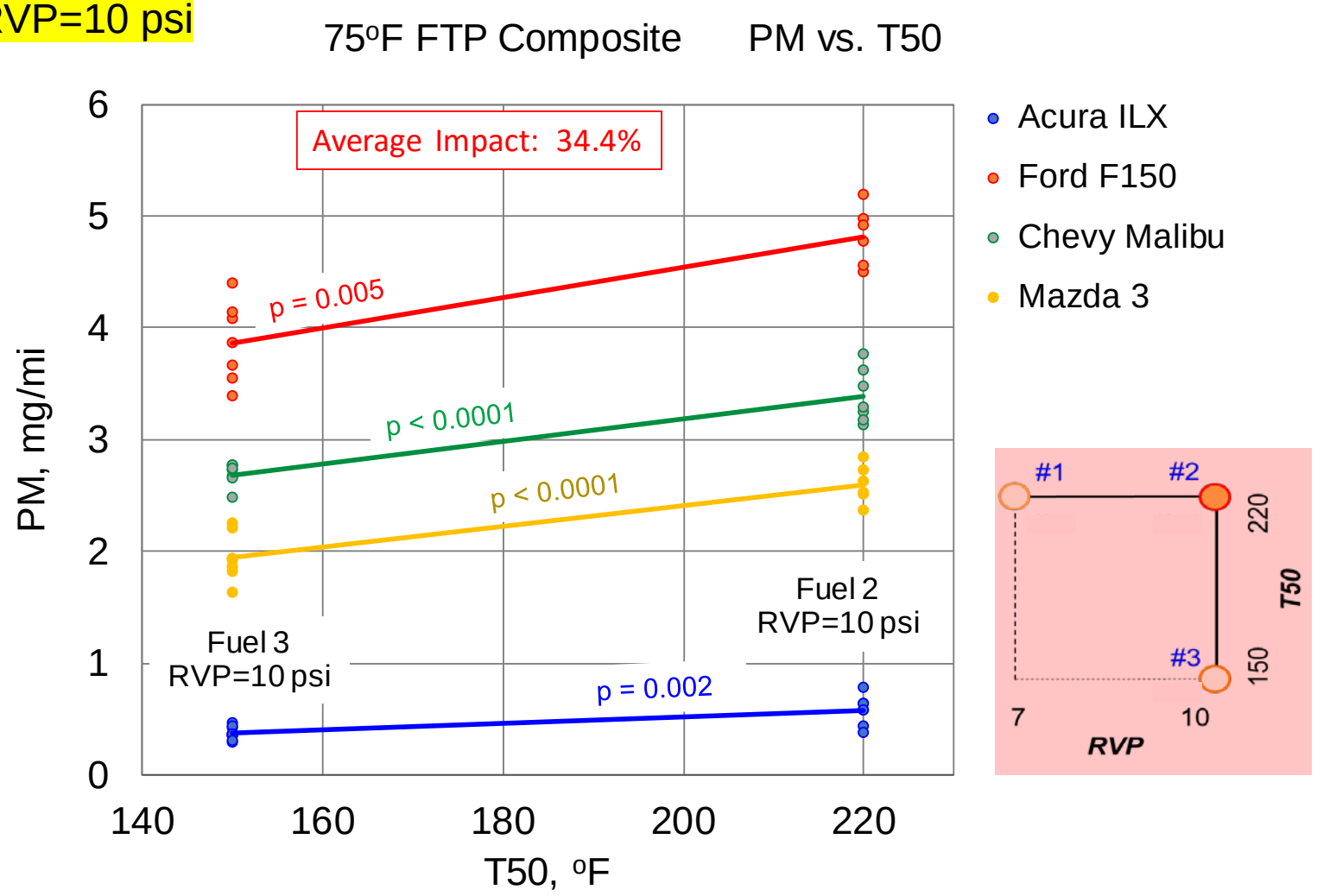


Test Program Design

- Test cycles: FTP and US06
- Measured parameters: PM, MSS soot, gaseous emissions, plus speciated VOCs and SVOCs on a subset of ~36 tests
- Emissions testing at EPA Ann Arbor lab
  - 4 vehicles tested at 75°F
  - 2 vehicles tested at 20°F
- Emissions testing at Environment Canada (ECCC)
  - 2 vehicles tested at 20°F. Neither was tested at EPA's lab
- Both labs used the same test protocols
- Nominal 6 test replicates per vehicle/fuel combination

T50 Impact on FTP Composite PM at 75°F

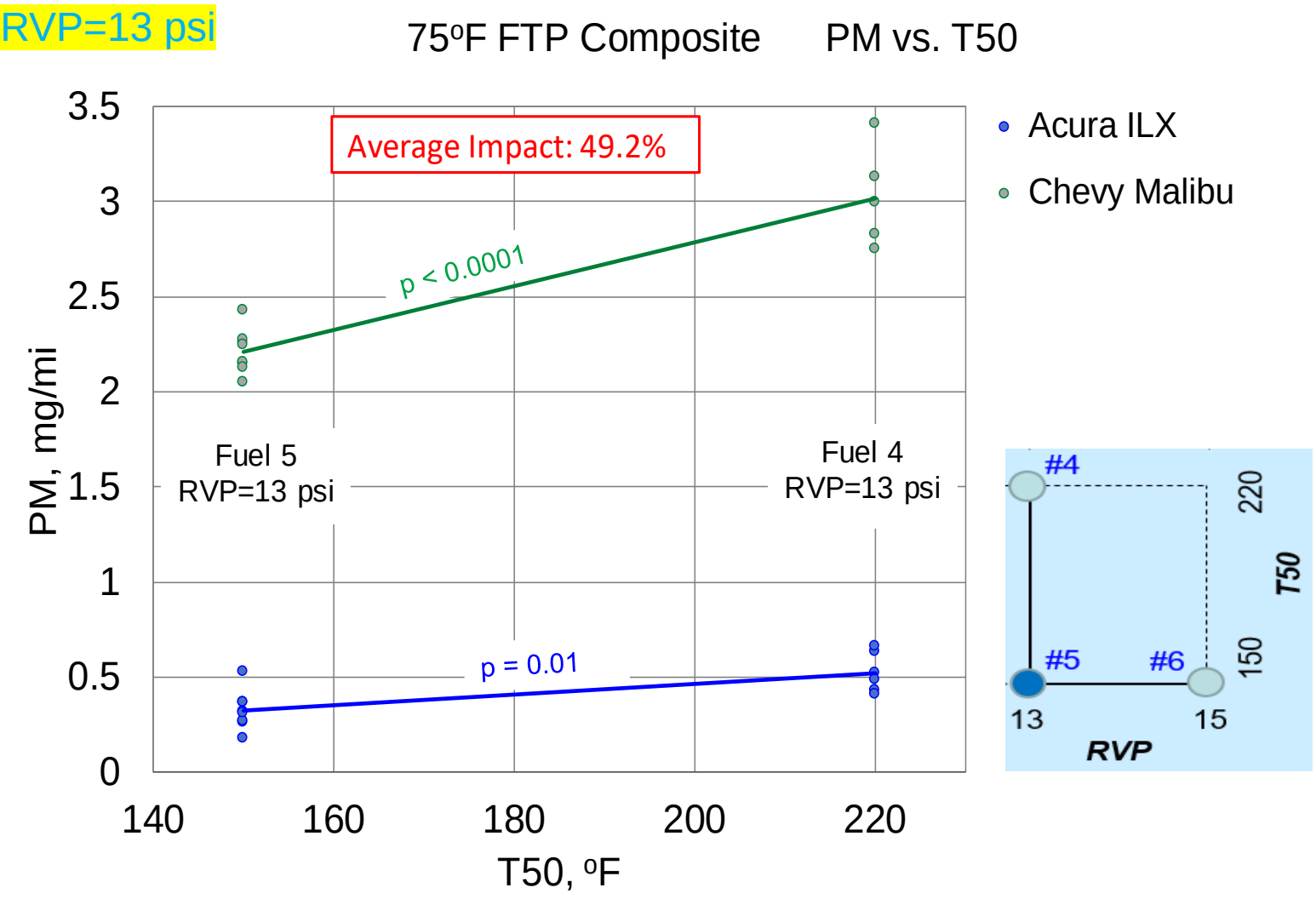
RVP=10 psi



Statistically Significant for All Vehicles

T50 Impact on FTP Composite PM at 75ºF

RVP=13 psi



Statistically Significant for All Vehicles

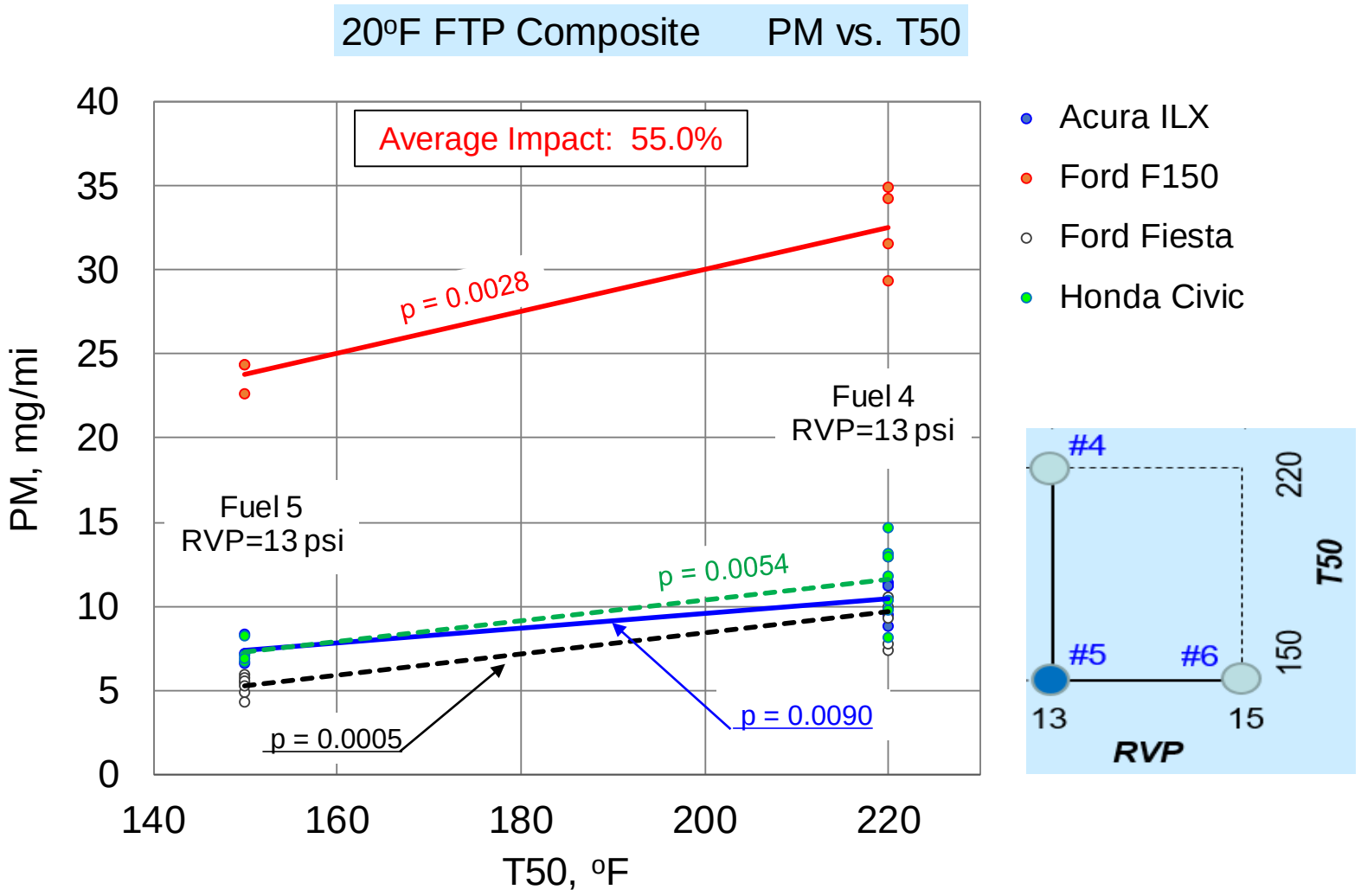
Average Impact of T50 and RVP on FTP and US06 PM at 75°F

Fuel Property Change	FTP				US06
	Bag 1	Bag 2	Bag 3	Composite	
T50 150°F » 220°F @RVP = 10 psi	40.7% All vehicles SS	23.9% 1 vehicle SS*	16.4% 2 vehicles SS	34.4% All vehicles SS	-0.1% NSS
T50 150°F » 220°F @RVP = 13 psi	61.9% All vehicles SS	4.1% NSS**	10.1% NSS	49.2% All vehicles SS	15.4% NSS
RVP 7 psi » 10 psi @T50 = 220°F	8.2% 1 vehicle SS	10.5% 1 vehicle SS	36.6% 2 vehicles SS	6.9% 1 vehicle SS	13.3% NSS

*SS: Statistically significant

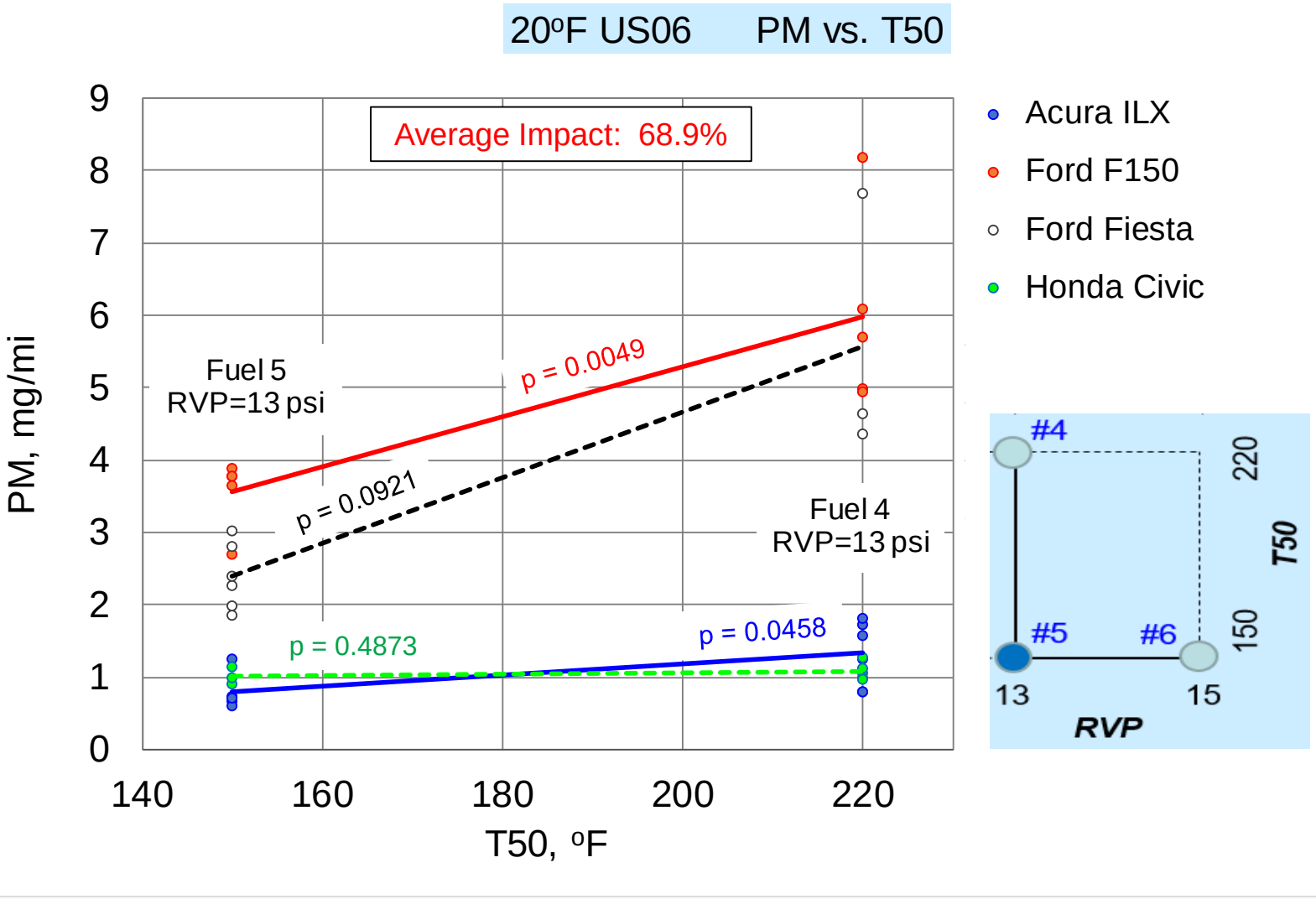
**NSS: No vehicles statistically significant

T50 Impact on FTP Composite PM at 20°F



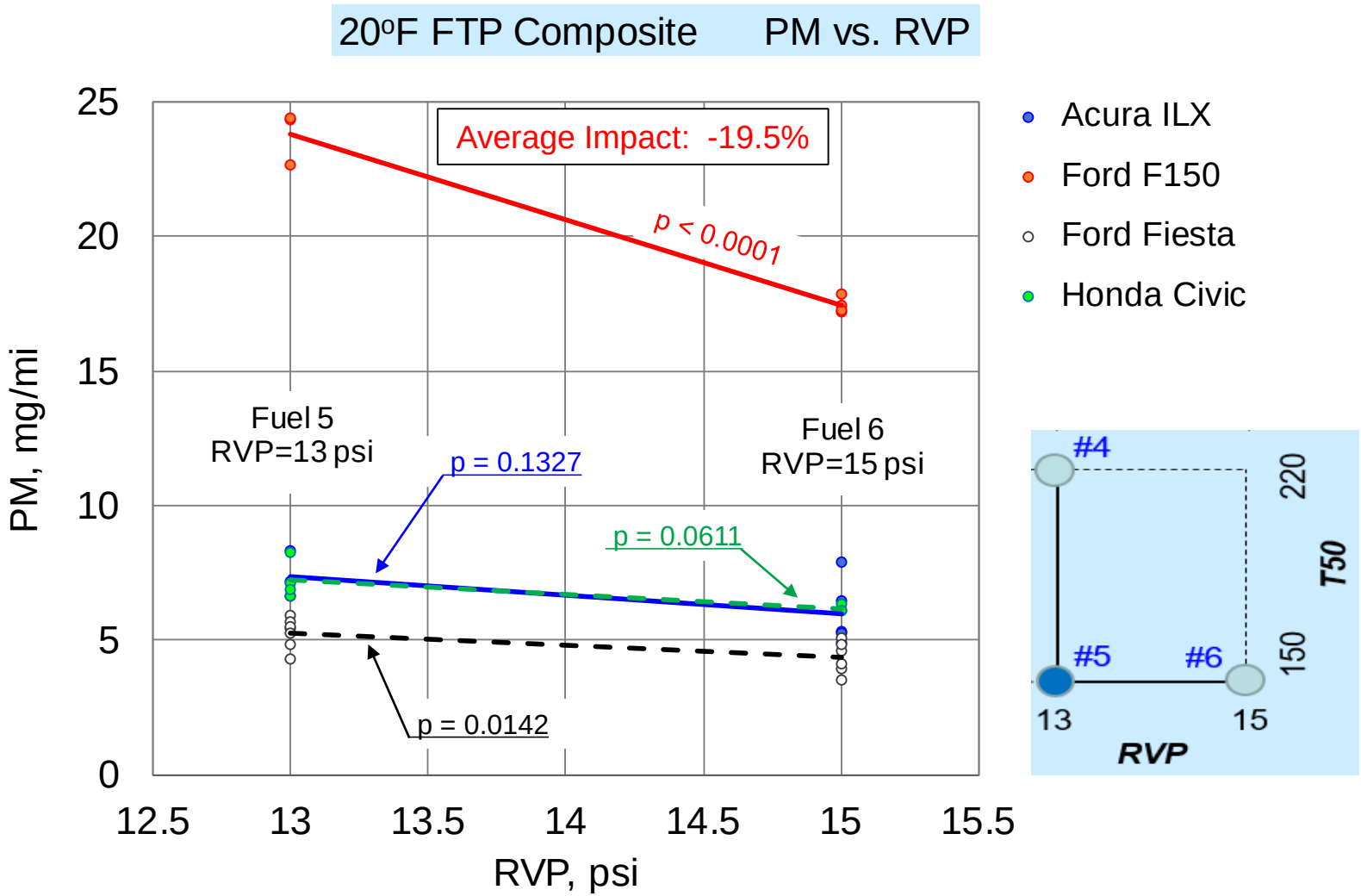
Statistically Significant for All Vehicles

T50 Impact on US06 PM at 20°F



Statistically Significant for 3 of 4 Vehicles

RVP Impact on FTP Composite PM at 20ºF



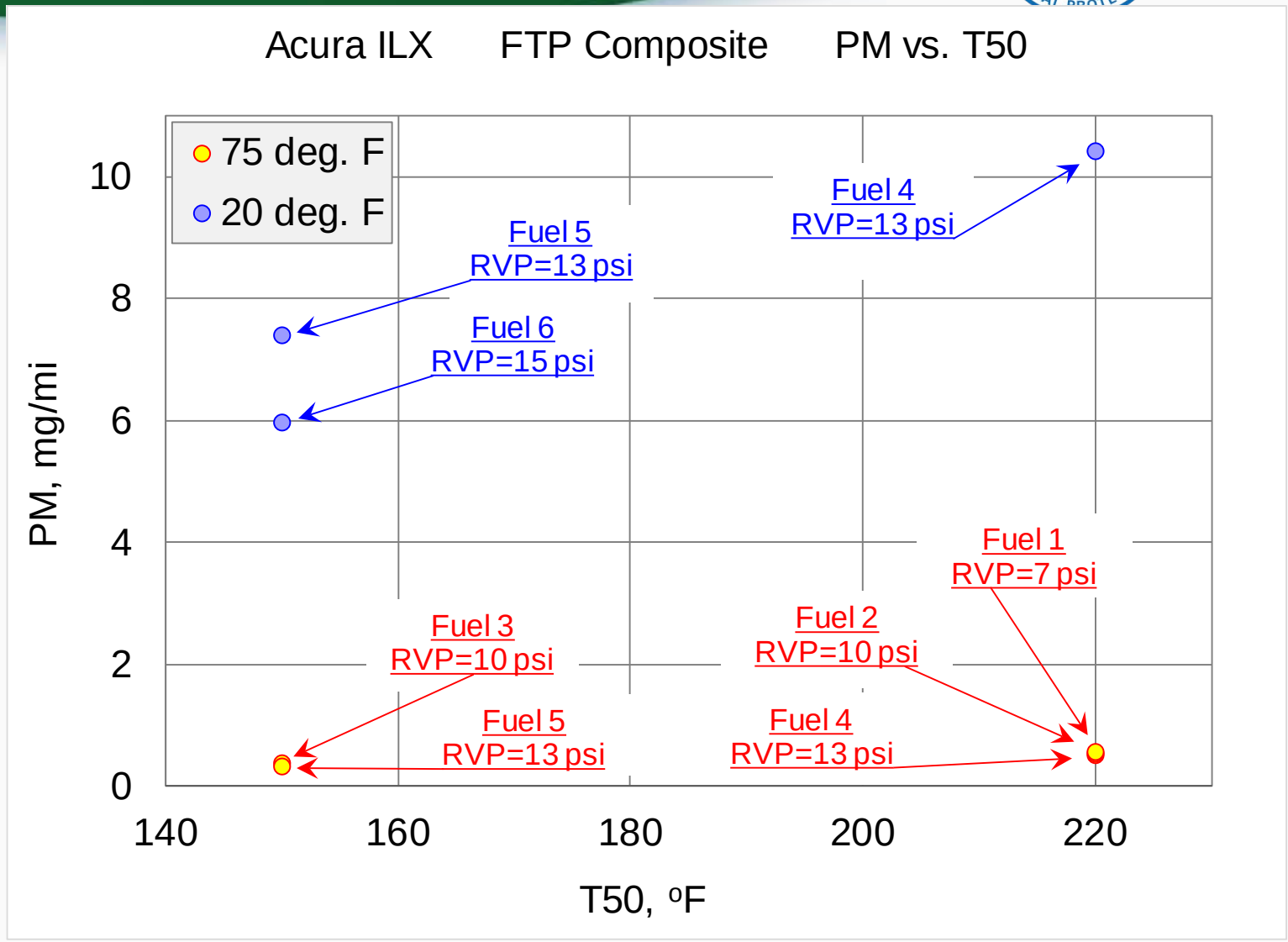
Statistically Significant for 3 of 4 Vehicles

Average Impact of T50 and RVP on FTP and US06 PM at 20°F

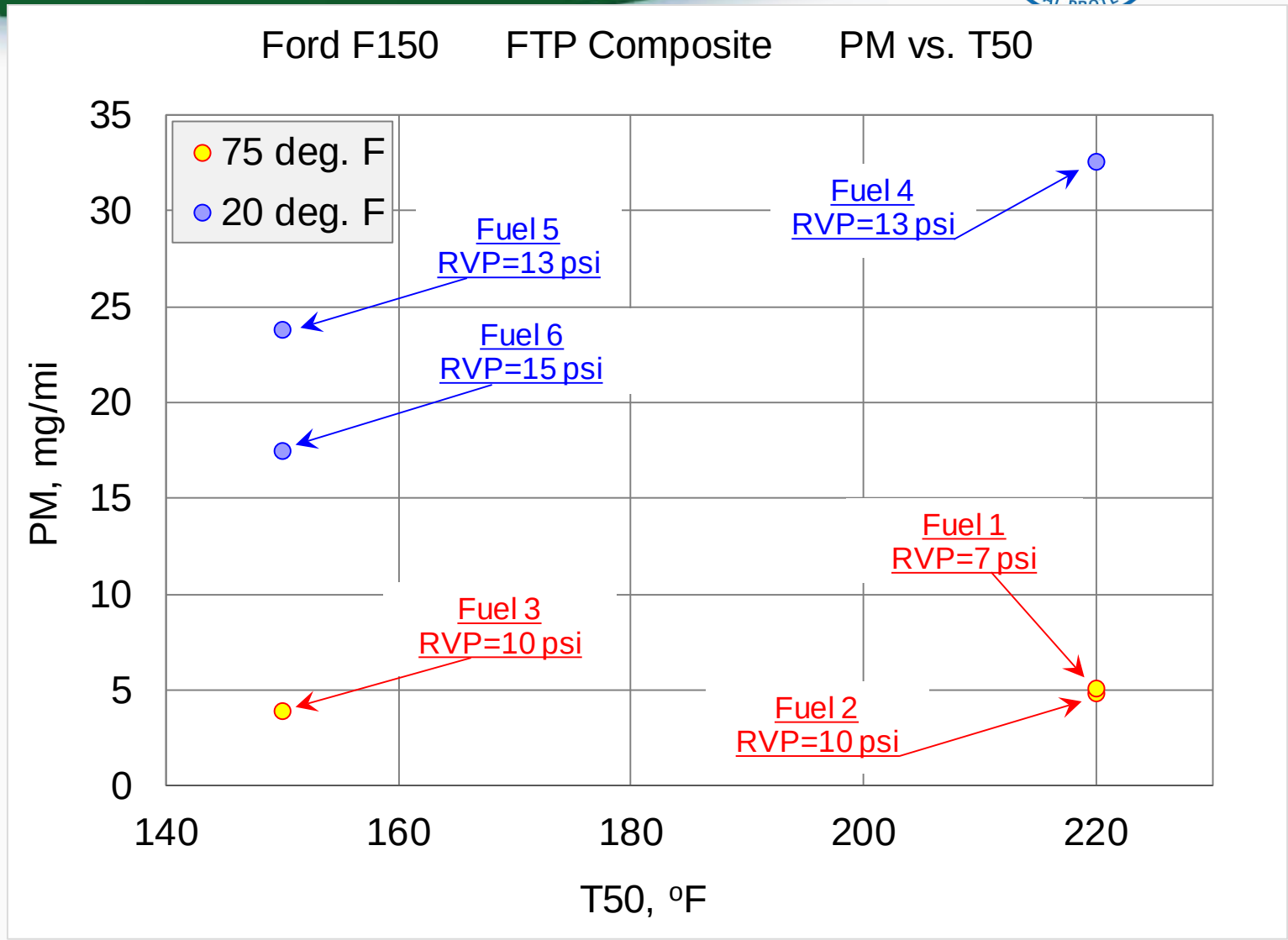
Fuel Property Change	FTP				US06
	Bag 1	Bag 2	Bag 3	Composite	
T50 150°F » 220°F @RVP = 13 psi	58.3% All vehicles SS*	37.1% 2 vehicles SS	34.6% 1 vehicle SS	55.0% All vehicles SS	68.9% 3 vehicles SS
RVP 13 psi » 15 psi @T50 = 150°F	-19.4% 3 vehicles SS	-18.9% 1 vehicle SS	-15.5% 2 vehicles SS	-19.5% 3 vehicles SS	-10.9% 1 vehicle SS

*SS: Statistically significant

Impact of Test Temp. Drop from 75 to 20°F on FTP Comp. PM from Acura ILX: 20 – 23X Increase



Impact of Test Temp. Drop from 75 to 20ºF on FTP Comp. PM from Ford F150: 6-7X Increase



Conclusions

- T50 change from 150ºF to 220ºF resulted in statistically significant increases in Bag 1 and FTP composite PM emissions from all test vehicles both at 20ºF and 75ºF
- RVP change from 13 psi to 15 psi resulted in statistically significant reductions in FTP composite PM emissions from 3 of the 4 test vehicles at 20ºF
- The drop in ambient temperature from 75ºF to 20ºF resulted in a 6 to 7-fold and a 20 to 23-fold increase in FTP composite PM emissions from Ford F150 and Acura ILX, respectively
- The drop in test temperature from 75ºF to 20ºF has, by far, much greater impact on PM emissions from light-duty GDI vehicles than T50 or RVP
- Future test programs evaluating gasoline property impacts on PM emissions from light-duty vehicles should control for T50 and the RVP (low temperatures only), in addition to other fuel properties found significant in previous studies

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